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Alternative Approaches to Weed Management

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Introduction

Herbicide technology and use have been the focus of weed management research for the past several decades. Herbicides are an important component of weed management and will remain so for years to come. However, there is increasing pressure to improve the efficiency of herbicide use and develop alternative control methods. Herbicides are used on over 95% of the corn and soybean in the Corn Belt because of the presence of weeds and the need to minimize their adverse economic impacts. Large inputs of herbicides and tillage are needed to control weeds because of the lack of knowledge of weed biology and ecology, continuous production of summer annual row crops, and the absence of control alternatives. Currently, weed science has few, if any, alternatives to herbicides and tillage that are both economically and environmentally desirable.

Lack of weed control is perceived by many producers as the major deterrent to the development of alternative crop production systems. Society is also asking that we develop new solutions to weed problems. As pressure increases to reduce herbicide use, new approaches to weed management must be developed. Potential areas for research and development include, but are not limited to the following:

- new control techniques.
- improved knowledge of weed biology and ecology and it's implications to management.
- integrated management systems, including threshold and population dynamics models.
- redesigning cropping systems to better utilize resources and diversify the cropping environment.
- development of crop cultivars that are tolerant of or minimize weed interference.
- innovative tillage systems.
- site-specific management for herbicide use and weed population management.
- improved understanding of weed populations at the field and regional levels.

It is easy to criticize the herbicide intensive weed management systems currently in use on most of our cropland. However, it is difficult to provide alternative practices that meet the needs of crop producers. Development and implementation of new weed management systems will be a long-term process (if it occurs at all). The intent of this paper is to present some of the research that is currently being conducted to develop alternatives to current practices. The material presented is not intended to be all inclusive of research on alternative weed management and is influenced by author bias.

Weed Management Decision Aides

In an effort to increase the efficiency and level of information used in making weed management decisions, weed management decision aides have been developed (King et al., 1986; Miller et al., 1990; Renner and Black, 1991; Swinton and King, 1994; Wilkerson et al., 1991). Computerized decision aides can be grouped into three categories. The first are programs based on herbicide efficacy and aid in herbicide product selection (Miller et al., 1990; Renner and Black, 1991). Another type includes programs based on economic thresholds determined by counting emerged weed seedlings and are for postemergence control decisions (Wilkerson et al., 1991). The third type are based on weed seed populations in the soil and seedling population estimates combined with economic thresholds (King et al., 1986; Swinton and King, 1994). The third type of model can be used for a full range of herbicide application times and mechanical control operations and have the potential to predict weed seed bank dynamics over time.

Although weed management decision aides have been developed, field evaluation and validation has been limited. The objective of our research in Minnesota and Iowa is to evaluate a bioeconomic weed management model (Swinton and King, 1994) under field conditions. The model was compared to standard practices in terms of weed control, crop yields, economic returns, and to determine the impacts of model-generated weed control treatments on weed densities and control in the succeeding crop.

During three years of research (1991-1993) at Rosemount, MN, model-generated treatments controlled weeds as well as the standard herbicide in most instances, but usually accomplished control with different treatment strategies. Giant foxtail was the dominant species and therefore had the greatest impact on weed control recommendation. Densities of common lambsquarters and pigweed were also sufficient to require treatment. In 1991, both seed bank- and seedling-based models resulted in similar weed control and corn yields with less herbicide use than a standard treatment (Table 1). There were no differences in net margin among the model-generated and standard treatments. The models also reduced herbicide use compared to a standard in 1992. The seedling-based model resulted in weed control, corn yield, and net margin similar to the standard treatment. However, treatments based on the seed bank model yielded less corn than a standard treatment and had lower net margins. Seed bank-based treatments resulted in corn yields and net margin similar to the standard treatment in 1993, however, herbicide use was not always reduced. Corn yield and net margin was less using the seedling-based model than a standard treatment.

Any decision aid model may have limited value under high weed densities. A decision aid may be useful in tactic selection, but should not be expected to reduce herbicide use under these conditions. A decision aid will have greater value under low weed densities and as an aid in determining the need for follow up control. Further research on the usefulness of a bioeconomic weed management model under a wide range of production conditions will define its utility for improving economic and environmental aspects of weed management.

Research on the use of bioeconomic weed management models is continuing in central Iowa. Current research is focusing on expanding the weed species in the model, the effects of tillage systems on model predictions, and the long-term impacts on the weed seed bank and weed populations.

Spatial Distribution of Weeds

The spatial distribution of weeds within fields has major implications to precision farming. Spatial aggregation of weed populations has been shown to occur within crop production fields (Johnson et al., 1995; Mortensen et al., 1993). Aggregation in weed populations is not well understood, but appears to result from many interacting factors. Characteristics such as soil pH, organic matter content, texture, structure, microbial activity, moisture holding capacity, and slope are spatially variable within fields (Cambardella et al., 1994). These factors influence weed populations both through their effects on herbicide efficacy and differential effects on population biology of weed species. In addition, misapplication of herbicides allows patches of weeds to escape control and contributes to aggregation that cannot be attributed to biological variation. Since seed are usually dispersed a limited distance from the mother plant, the spatial distribution of seed from escaping plants further increases aggregation.

Variability in weed populations has been largely ignored in designing pest management strategies. The void in the understanding of weed population distribution has become evident due to recent interest in applying herbicide based on weed distribution in fields rather than via broadcast application. Most research on the interaction of weeds with other aspects of the cropping system has assumed that weeds are uniformly distributed in fields. Little attention has been given to weed distribution and dispersal. Recent studies indicate that weeds occur in multispecific, nonhomogeneous populations within a field (Buhler and Kohler, 1994; Johnson et al., 1995; Mortensen et al., 1993). In a study of several farm fields in eastern Nebraska (Mortensen et al., 1993), all species encountered occurred in aggregated or patchy distributions. Since seed from most annual weed species are dispersed only a short distance from the mother plant, spatial distributions within fields should be stable over time (Johnson et al., 1995). In a corn field central Iowa (Buhler and Kohler, 1994), several weed species were present and found in aggregated distributions. Preliminary analysis of the Iowa data indicated a strong correlation between the different soil types present in the field and weed density and species composition.

Smother Plants for Weed Control

Smother plants are specialized cover crops with an ability to suppress weeds, and may prove to be an alternative to herbicides in some situations. An effective smother plant provides weed control without herbicide use, reduces soil erosion, and improves soil quality. Spring-seeded smother plants may avoid the problems associated with previously tested living mulch systems (DeHaan et al., 1994). Competition from spring-seeded smother plants may be easier to manage than winter annual and perennial species because planting patterns and rates can be chosen at planting time in response to environment and other factors. In addition, herbicide will not be necessary to eliminate the smother plant if its life cycle is of appropriate length.

A short-cycle brassica and four varieties of annual medic were evaluated as spring-seeded smother plants for weed control in corn and soybean in a preliminary experiment near Ames in 1994. Smother plant seed were planted in a 25-cm band over the row at the time of planting at two planting dates for each crop. Interrow weeds were controlled with cultivation. Results of this experiment varied by crop and planting date. The most encouraging results were obtained with corn and smother plants planted on April 25. Moist soil conditions following planting resulted in excellent establishment of the smother plant, resulting in up to 90% weed suppression (Table 2). The short-cycle brassica and Sava medic were particularly effective in suppressing both annual grass and broadleaf weeds.

Smother plants were allowed to naturally complete their life cycle. This resulted in smother plant growth until early-August in some cases. This extended period of competition inhibited corn growth (data not shown). Inhibition was greatest with short-cycle brassica, possibly because of an allelopathic effect of the brassica on the corn (Kirkegaard, 1994). Corn appeared to recover from most of the competition by maturity, however, yields were reduced compared to the check with Caliph medic and short-cycle brassica (Table 2). Yields with Sava, Santiago, and Paraggio medics were not statistically different from the check.

This research was expanded in 1995 with the aid of a grant from the Leopold Center for Sustainable Agriculture. Results of this research were not available at the time this reported was prepared.

Tillage During Darkness

Field research was conducted at Rosemount, MN in 1994 and 1995 to determine the effect of tillage in the dark on the emergence of 13 annual weed species under uniform soil and environmental conditions. The experiment was conducted in a weed nursery with 13 annual weed species grown individually in 5-m-wide strips. The soil was Waukegon silt loam with 4.5% organic matter. The entire experimental area was moldboard plowed the previous fall. The experimental design was a randomized complete block, split plot with six replications. Main plot treatments were date of tillage (mid- and late-May) and subplots were secondary tillage treatments. Secondary tillage was conducted with a tandem disk operated 8 cm deep. Treatments included: two passes with the disk in the light (2x light), one pass in the light followed by the second pass in the dark (1x light/1x dark), two passes in the dark (2x dark), and no secondary tillage with glyphosate to control emerged weeds (glyphosate). Tillage operations in the light were conducted between 2:00 and 4:00 pm and dark operations were conducted between 11:00 pm and midnight. Treatment effects were evaluated by weed counts 15, 30, and 50 days after tillage.

Emergence of the annual grass species (barnyardgrass, green foxtail, giant foxtail, and yellow foxtail) was not affected by secondary tillage methods. Emergence of large-seeded broadleaf species (common cocklebur, giant ragweed, and Velvetleaf) was similar following tillage in the light or dark. However, total emergence of the large-seeded species was often less when glyphosate replaced secondary tillage. Emergence of small-seeded broadleaf species (common lambsquarters, common ragweed, eastern black nightshade, pigweed species, Pennsylvania smartweed, and wild mustard) was affected by the time of secondary tillage (Table 3). Reduction in emergence when tillage was conducted in the dark varied by species and date of tillage. Compared to secondary tillage in the light, tillage in the dark reduced Pennsylvania smartweed emergence by 80% following tillage on May 12, 1994. Emergence reduction with other small-seeded species ranged from 30 to 70%. Replacing tillage with glyphosate often resulted in reductions in emergence similar to those observed with tillage in the dark.

Based on the results of this experiment conducted at a single site, it appears tillage in the dark may have potential as a component of integrated weed management. However, it must be noted that several important weed species where insensitive to tillage in the dark. Additional research is needed to determine the light sensitivity of various weed species, the effects of tillage depth, and types of tillage implements. Since it will be very difficult to conduct all operations in the absence of light, research is also needed to determine where it best fits into cropping systems.

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Table 1. Corn response and gross return to weed control at Rosemount, MN in 1991, 1992, and 1993.

Treatment	Corn yield			Gross return to weed control		
	1991	1992	1993	1991	1992	1993
	kg ha^{-2}			$\$$ ha^{-2}		
Seed bank model	11300	7840	10950	636	278	639
Flexible seed bank model	NA[a]	8133	11810	NA	296	682
Seedling model	11100	9380	10600	601	409	620
Standard herbicide	11600	9910	12130	659	439	728
Standard mechanical	8870	5440	7030	465	103	340
Weed-free	11900	10410	11630	---	---	---
Weedy	3100	3950	2750	0	0	0
LSD (0.05)	1200	1130	1450	70	63	110

[a]Treatment not included in 1991.

Table 2. Effect of smother plants on weed densities and corn yield at Ames, IA in 1994.

Smother plant	Weed density: Annual grass	Weed density: Annual broadleaf	Weed density: Total	Corn yield
	--------------- plants per m of row		--------------	kg ha^{-1}
Short-cycle brassica	1	0	1	7550
Sava medic	2	1	3	8580
Santiago medic	4	5	9	8450
Caliph medic	18	4	22	8080
Paraggio medic	19	6	25	8440
Check	17	11	28	9700

Table 3. Effects of secondary tillage time on emergence of small-seeded annual broadleaf species at Rosemount, MN in 1994. Tillage was conducted on May 12 and weeds were counted 30 days later.

Species	2x dark	1x light/ 1x dark	Glyphosate	LSD (0.05)
	--------- % of emergence following 2x light ----------			
Common lambsquarters	30	63	30	14
Common ragweed	52	76	27	18
Eastern black nightshade	45	50	72	17
Pennsylvania smartweed	20	85	64	23
Pigweed species	60	84	35	16
Wild mustard	67	76	21	12